17 Years of Surface Changes on Io: Galileo SSI Results

A. McEwen[1], L. Keszthelyi[1], D. Simonelli[2], T. Johnson[3], M. Carr[4], R. Greeley[5], and the Galileo SSI team.
[1] LPL, Univ. Arizona, Tucson, AZ; [2] Cornell Univ., Ithaca, NY; [3] JPL, Pasadena, CA; [4] USGS, Menlo Park, CA; [5] Arizona State Univ., Tempe, AZ.

Observations of Io by Galileo's Solid State Imaging (SSI) experiment during the first half of the nominal satellite tour are described in a companion abstract [1]. Here we summarize preliminary results on one of the high-priority science objectives: comparison to Voyager spacecraft images of Io acquired in 1979 to map surface changes. These changes and other observations (especially thermal) indicate that there is a diverse range of volcanic activity on Io [2].

Distinguishing real surface changes from apparent changes is complicated by (1) differences between the color bandpasses of the Voyager and Galileo imaging systems, (2) variations in photometric geometry, and (3) variations in spatial resolution. We make comparisons only with the green and violet bandpasses from each camera, which have similar spectral responses. Io can change appearance dramatically as a function of phase angle, including striking contrast reversals and color changes [3]. Therefore we only have confidence at this time in comparisons between images acquired at comparable phase angles. Colors on Io also change slightly with emission angle, which we normalize to first order via application of wavelength-dependent limb-darkening corrections from [4]. Coregistration to subpixel accuracy and matching spatial resolutions are important for comparison of features near the limits of resolution [5], but are not important for the well-resolved features described below. Minor color and albedo differences remain in spite of comparable bandpasses and phase angles, so we also derive and apply multiplicative and additive corrections that produce the best overall (full-disk) match between Voyager and Galileo images in each color.

Only two full-disk SSI color sets have been acquired in orbits G1-C3 which are reasonably well-matched to the photometric geometries and resolutions of Voyager images: (1) the Loki hemisphere (longitude 260-30) imaged by Voyager 2 at 20 degrees phase and 13 km/pixel and by SSI G1 at 25 degrees phase and 15 km/px, and (2) the Prometheus hemisphere (longitude 95-255) imaged by Voyager 1 at 8 degrees phase and 6 km/pixel and by GLL G2 at 4 degrees phase and 5 km/px. The images were reprojected to the same geometry and scale, and color images were created by displaying the green filter as red, a red+violet average as green, and the violet as blue. A series of images showing these comparisons are available via the Galileo web pages (http://www.jpl.nasa.gov/galileo/sepo/atjup/newim.html).

Especially interesting areas are discussed below:

Ra Patera. Dramatic changes are apparent surrounding the shield volcano Ra Patera (325° W, 8° S), including new flows and pyroclastic deposits. A brightening at Ra Patera was first seen from HST images, and is known to have occurred between March 1994 and July 1995 [5]. The presence of new bright yellow deposits with flow-like morphologies and the absense of intense hot spots at this location [6] is consistent with the eruption of sulfur flows, as previously proposed [7] for Ra Patera. SSI also discovered an active plume ~75 km high at Ra Patera during G1, but the plume was not visible during G2 or C3 [1,8]. Bright yellow duffuse deposits just west and south of Ra's vent were anomalously bright on Io's nightside in a red-filter G1 image (but not violet, green, or 756-nm images). The origin of this brightening remains a mystery.

Loki. Loki Patera (307° W, 15° N) has been by far the most energetic hot spot on Io over the past 17 years [9], so we expected to see dramatic surface changes. Instead, the changes near Loki are relatively small, including a lengthening of the dark linear feature northeast of Loki Patera and darkening of a spot just west of Loki. Loki Patera remains a very low-albedo feature, unlike Amaterasu Patera (307° W, 38° N) which has brightened substantially since 1979. High-temperature outbursts and thermal models suggest that Loki may be dominated by silicate volcanism [9-11], but only relatively small areas (for Io, up to a few tens of km^2) need to be resurfaced by high-temperature lavas to account for the infrared observations. Therefore, the style of volcanism at Loki appears to be very different from that at Ra Patera. Note that the Voyager-era plumes at Loki (which were erupting from both ends of the dark linear feature) have not been seen during the first Galileo orbits, including observations specially target for the Loki plumes. Also, the thermal output from Loki has been unusually low during 1996 [12].

Surt and Aten. Several large-scale changes occurred between Voyagers 1 and 2, including Pelesized plume deposits surrounding Surt (338° W, 46° N) and Aten Patera (311° W, 48° S) and darkening of their caldera floors [13]. In Galileo G1 images these regions appear more similar to the Voyager 1 images than to the Voyager 2 images! Processes such as phase transformations or sublimation must alter deposits such as plume fallout and dark caldera floor materials over timescales of years to decades. We suspect that the fresh plume deposits were bright red, similar to those of Pele [5], because of similarities to Pele in plume fallout areas and colors (as seen by Voyager). Bright red materials on Io may be due to metastable short-chain sulfur species [5]. Indeed we see elsewhere on Io that there is a close association between bright red deposits and high-temperature hot spots [2, 14, 15]. The Voyager and Galileo images of Surt and Aten plume deposits also suggest that the dark red material is longer-lived at higher latitudes, consistent with temperature-dependent phase transformations or sublimation. We suspect that the reddish polar regions of Io are largely due to reddish pyroclastics that are longer-lived at lower temperatures.

Prometheus. Orbit G2 provided our first look at Prometheus (152° W, 2° S), and revealed an active plume and a new dark lava flow. NIMS has detected a hot spot at Prometheus [14]. Comparison to Voyager images reveals that the plume is erupting from a position about 70 km west of the 1979 vent. The dark lava flow, which at first appears to have erupted from the current plume vent and flowed to the east, may have actually erupted from the Voyager-era vent and flowed to the west (and with a smaller flow to the north). If the latter interpretation is correct, then the plume is erupting from the margin of the flow, perhaps volatilizing near-surface SO_2 frost deposits. Prometheus was also active during C3, and we suspect that it was active in G1 based on the eclipse image. Has this plume been continuously active for 17 years? It has about the same dimensions and brightness as in 1979.

Volund. G1 images revealed a small plume (~50 km high) erupting from a position (173° W, 18° N) that is a few degrees south of the Voyager-era plume Volund. The G1 eclipse image also showed an intense hot spot (>700 K) at this location, surrounded by an extended diffuse glow [2]. G2 and C3 images revealed dramatic surface changes in this region. There is a low-albedo linear feature (possible fissure-fed flows) about 150 km long, surrounded by more diffuse deposits, none of which was apparent in Voyager images.

Marduk. The G1 eclipse image revealed a high-temperature (>700 K) hot spot at the position of the Voyager-era plume Marduk (210° W, 27° S). The G2-Voyager comparison shows extensive surface changes, including dark flows and a bright red deposit (first detected by HST [5]). No active plume has been detected by Galileo.

Culann. The G1 eclipse image and G2 plume inventory both appear (marginally) to show a small (< 50 km high) plume at Culann Patera (160° W, 19° S). G2 images reveal extensive surface changes compared to Voyager, verifying a change first detected from HST [5]. NIMS has detected a hot spot at Culann [14]. Both low-albedo flows and diffuse bright red materials are present, as is the case near most current high-temperature hot spots [15].

There are about a dozen or more additional large-scale (> 50 km) surface changes on Io and many smaller changes.

References

[1] McEwen, A., et al., Observations of Io by SSI during the first half of the Galileo tour of Jupiter, this volume. [2] Belton, M.J.S., et al. (1996) Galileo's first images of Jupiter and the Galilean satellites. Science 274, 377-385. [3] Simonelli, D., et al., Io: Evidence for major variations in regolith properties, this volume. [4] McEwen, A. (1988) Global color and albedo variations on Io. Icarus 73, 385-426. [5] Spencer, J.R., et al. (1997) Volcanic resurfacing of Io: Post-repair HST Imaging. Icarus, in press. [6] J. Spencer and others, personal communication. [7] Pieri, D.C., et al. (1984) Sulfur flows of Ra Patera, Io, Icarus 60, 685. [8] McEwen, A., et al., Io: Where have all the visible plumes gone?, this volume. [9] Spencer, J.R., and N.M. Schneider (1996) Io on the eve of the Galileo mission. Annu. Rev. Earth Planet. Sci. 24, 125-190. [10] Carr, M.H. (1986) Silicate volcanism on Io. JGR 91, 3521. [11] Blaney, D.L., et al. (1995) Volcanic eruptions on Io: Heat flow, resurfacing, and lava composition. Icarus 113, 220. [12] D. Blaney, personal communication. [13] McEwen, A.S., and L.A. Soderblom (1983) Two classes of volcanic plumes on Io. Icarus 55, 191. [14] Lopes, R. et al., Monitoring of Io's volcanic activity using Galileo's Near Infrared Mapping Spectrometer (NIMS), this volume. [15] Geissler, P., et al., Global color variations on Io, this volume.